The Association between Periodontal Disease and Root/Coronal Caries

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Running Title: Periodontitis and Caries Association

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Abstract

Objectives: To examine if there is an association between periodontal disease and each of root caries and coronal caries among adults (aged 35 and over), using a nationally representative sample of adults in England, Northern Ireland and Wales.

Material and Methods: In this cross-sectional study, Data from the Adult Dental Health Survey 2009 were used. Adults aged 35 years or older who had periodontal and caries assessment were included. Two sets of negative binomial regression were conducted for each of coronal caries and root caries adjusting for periodontal diseases, dental visits, country, sex, age, education, job classification, oral hygiene and smoking.

Results: Overall, 4738 were included in the analysis. Periodontal disease was significantly associated with each of coronal and root caries. In the fully adjusted model, those with PD/ LoA ≥4mm had 1.03 rate ratio (RR) for coronal caries (95%CI: 1.01-1.05). In the model pertaining to root caries, the RR for those with periodontitis was 1.23 (95%CI: 1.16-1.30). Smoking, sex, age, oral hygiene were the variables that showed a consistent and significant association with coronal and root caries.

Conclusion: Individuals with periodontal diseases appeared to be at higher risk of coronal and root caries. While root exposure could be a plausible explanation for the relationship between periodontitis and root caries, the association with coronal caries could be attributed to the irritation of carious cavities, or common risk factors such as poor oral hygiene, or co-occurrence of different health risk behaviours related to both caries and periodontitis and socioeconomic conditions.

Keywords: Dental Caries, Root Caries, Periodontal Diseases

CLINICAL RELEVANCE

Scientific rationale: periodontal diseases and dental caries share some common risk factors, however it is not clear if periodontal disease is associated with both of coronal and root caries.

Principle findings: periodontal disease is associated with each of coronal and root caries.

Practical implication: findings suggest the need for comprehensive preventive/ health promotion intervention to tackle both periodontal diseases and dental caries.

Introduction

Dental caries and periodontal disease are the most prevalent chronic multifactorial diseases affecting adults around the globe (1, 2). The study of the association between periodontitis and dental caries has been an area of interest in the literature during the last several decades. Both conditions share some risk factors such as age, poor oral hygiene, low socioeconomic position, poor diet, host genetics and smoking. Furthermore, studies have identified gingival recession as a risk factor for root caries(3). Root caries occurs after the exposure of the root surface to the oral environment. This could be attributed to the loss of periodontal attachment in advanced periodontitis(4).

The main risk factors for both conditions' development can also be attributed to host genetics and poor oral hygiene. Recent studies demonstrated a moderate role of genetic component causing periodontal disease and leading to caries susceptibility(1).

Poor oral hygiene was found to have a strong association with both periodontitis and dental caries(2). Other risk factors have been shown to be related to both condition such as age, ethnicity, country of residence, socioeconomic position, education, utilisation of dental services, smoking and carbohydrate intake(1, 5).

There is contradictory evidence about the association between caries and periodontal diseases. Few studies found that there is no association between the two diseases(6, 7). Other studies reported a negative relationship between periodontal disease and caries(8, 9), while other studies found a strong positive association between periodontal disease and root caries(10, 11), and between periodontal disease and coronal caries(5, 12-14).

Although establishing periodontitis as a predictor for both of coronal and root caries might help improving the risk profile for these two conditions, to the extent of our knowledge, there are no

studies that examined these associations in the same population using a nationally representative sample(10, 15). Therefore, we set out to test the association of periodontal disease with each of coronal and root caries taken into consideration differences in sex, age, oral hygiene, socioeconomic position and sugar consumption using a nationally representative sample of adults from England, Wales and Northern Ireland.

Materials and Methods

Study population:

The study population was from the Adult Dental Health Survey (ADHS) 2009, a cross-sectional nationally representative sample of adults 16 years old and over living in England, Northern Ireland and Wales. The process of selecting participants was a two-stage cluster sample. The first primary sampling unit (PSU) compromised of 253 from England and Wales while the other PSU compromised 15 from Northern Ireland. Both of PSU contained two different postcodes, each postcode sampled 25 addresses and thus resulted in a total sample size of 13,509 individuals. Of those 11,380 (84%) individuals agreed to participate in home interviews, and 6,469 (61%) participants out of total were clinically examined. Only 4,905 participants aged 35 and older had a basic periodontal examination (representing (76%) of those with clinical examination). Participants who had complete data and aged 35 years and more were included in the analysis (4,738), 96.5% of those with basic periodontal examination (Figure 1). Further description and information of the survey and the frame of the sampling have been reported elsewhere(14).

Measurements:

The majority of the clinical examiners were trained dentists working for the National Health Service (n=77). All dentists had to attend one of three training sessions, each of the sessions

covered the following areas detailed clinical review via CD-ROM, examination practice using volunteers, calibration training. The calibration training included recording of plaque, calculus and caries (coronal and root) diagnosis. However, there were no calibration of periodontal pockets measurements. The interviewers received training and were responsible for conducting the initial interviews and for recording data obtained from clinical examinations. The information obtained from the clinical examinations were the condition of the tooth (coronal and root surface) and periodontal examination. Caries diagnostic criteria for non-cavitated dentin was underline dentin shadow(15, 16). ADHS included questions on the socio-demographic data and dental behaviours.

Variables:

Outcome variables (coronal caries and root caries)

The two main outcome variables were count variables for DMFT and root caries. As the objective of the study was to assess the relationship between periodontitis and the cumulative caries experience, active and treated caries, coronal caries was indicated by the sum of decayed, missing and filled teeth (DMFT) score as it reflects current active caries and caries that was treated by filling or extraction. Root caries was only indicated by the sum of decayed and filled roots as the survey did not specify if a tooth was extracted because of root caries (15, 16).

Explanatory variables (periodontitis)

The main explanatory variable of this study was periodontitis. It was assessed using the basic periodontal examination (BPE) and it was conducted only for adults who were 35 years and older. The examination included a recording of pocket depth (PD) on six sites of the tooth for all teeth in the mouth. Whereas periodontal examination for those aged 16 to 34 was only conducted on two sites of the tooth (the mesial site and distal), thus the analysis was limited to

participants aged 35 and older. Finally, loss of attachment (LoA) was only performed for participants who were 55 years and older. The decision to have different periodontal assessments for different age groups was based on the know level of periodontal diseases and gingival recession for each group and considered ethical factors and time constraints in this national survey.

A CPI type C probe and a mirror were used for examination. For each sextant the worst score was recorded using the following codes: up to 3.5mm, 4-5.5mm, 6-8.5mm and higher than 9 mm. The definition of periodontal disease was assigned as having one or more site with PD or LoA of 4mm or higher(16). In this study the variable used for determining periodontitis was a composite measure, and it was defined as having any PD or LoA of 4 mm or more, and it was recorded either (PD or LOA <4 mm OR PD or LOA $\geq$4 mm). This variable reflects pocket depth or loss of attachments for those aged 55 and over, and only pocket depth for those aged 35 and under 55. This variable was created in the original survey.

Covariates:

Covariates accounted for during the statistical analysis were demographic factors: age (35-44, 45-54 and 55+), gender, country of residence (England, Wales, Northern Ireland). Socioeconomic factors: education (no qualification, below degree level qualification, at degree level qualification) and job classification (managerial/professional, intermediate, routine and manual, never worked). Behavioural factors: frequency of dental visit (at least every 6 months, at least once a year, less than once every year), toothbrushing as proxy for oral hygiene (twice a day and more, once a day or less), smoking (current smoker, former smoker, never smoker) and sugar consumption. The original variables for sugar intake was computed based on the answers to three questions related to the number of times of consumption of cakes, sweets and fizzy drinks. Each of the sugary items was assigned to one of the five scores as follows: 6 or

more times a week, 3-5times a week, 1-2times a week, less than once a week, and rarely or never. On a 4-point response scale, the frequency of sugar intake was re-coded into (six times a week, three times a week, one time a week, less than once a week or never). Each value was given a score as follow: six times a week (6/7 days= 0.86), three times a week (3/7 days= 0.43), once a week (1/7 days= 0.14) and less than once per week or never (0). Weighted scores were chosen to match the lower frequency of consumption of each response. Then, a new variable "sugar consumption" was computed and it was used as a continuous variable as a sum weighted scores of the three sugary items.

Data Analysis:

STATA version 14 was used for conducting the analysis (Stata Corp LP, College Station, TX, USA). Survey command was used throughout the analysis to account for examination weight. Participants with complete data and aged 35 years and more with the BPE were included in the analysis. Furthermore, exclusion from the analysis was done for participants with less than two teeth (n=9), 0.1%. Participants excluded for having missing periodontal data were (n=57) 0.2%, frequency of dental visit (n=49) 1.0% and education (n=5) 0.1%. Accordingly, a sample of 4738 participants was included in this analysis.

The first step in the analysis was the assessment of the distribution of all variables, age, gender, country, DMFT and root caries, and indicators for the socioeconomic position (education, job classification). The distributions of each of coronal and root caries within each of the study variables were also assessed. The distributions of DMFT components and periodontitis by age groups were also assessed. Finally, two sets of Negative Binomial Regression model were used for examining the association between periodontitis and each of coronal and root caries and were adjusted for age, sex, country of residence, ethnicity, education, job classification, smoking, dental visit, oral hygiene, periodontitis and sugar consumption.

Results

A total of 4738 participants were included in the analysis. The socio-demographic and behavioural characteristics of all participants are presented in Table 1. The study sample included in the analysis and the participant excluded due to missing data or not fitting into the inclusion criteria showed no differences in demographic characteristics. The mean of frequency of sugar consumption was 0.92 (95%CI 0.90-0.94) per day.

Mean DMFT among participants with periodontitis was 17.01, whereas among the participants without periodontitis was 15.46. The means of root caries among participants with periodontitis and without periodontitis were 10.03, and 7.64, respectively.

The analysed sample constituted of England (91.5%), Wales (5.4%) and Northern Ireland (2.9%) population, and the majority of the sample were in the age group from 55 years and more (45.8%). Overall, 57.08% had qualification below degree level. Majority of the study sample reported visiting a dental clinic every 6 months (55.6%), brushing their teeth twice or more (74.4%) and never smoking (44.4%) (Table 1). Table 2 shows the distribution of DMFT components and periodontitis by age groups.

The distribution of caries (DMFT and root caries) within different groups of variables used in the analysis are shown in (Table 1). Mean DMFT and root caries were higher among White adults, those with lower education, and those having PD or LoA of 4 mm or more. Furthermore, the mean of DMFT and root caries showed a regular pattern among age groups, both conditions increased with age, but DMFT was higher among females, whereas root caries was higher among males. The former smokers' group had the highest DMFT, while the current smokers' group had the highest mean of root caries.

Results of the Negative Binomial Regression analysis are displayed in (Table 3) reporting rate ratio (RR) of DMFT outcome by demographic, socioeconomic and behavioural factors. After adjusting for covariates, DMFT was significantly associated with all of the variables except for frequency of dental visit and job classification. Adults with periodontitis (having PD or LoA ≥4 mm) had a significant association with DMFT (RR: 1.03, 95%CI: 1.01-1.05). Furthermore, adults aged 55 and above, female and Northern Ireland residents had higher rates of DMFT. Additionally, those who had qualification below degree level, and higher sugar consumption were significantly associated with DMFT. Significant associations were observed among the

smoking group as both former RR: 0.92 (95% CI: 0.89 - 0.96), and never smoker RR: 0.90 (95%CI: 0.87-0.93) had significantly lower rates of DMFT than current smokers.

Table 4 shows results from regression model for root caries. In a model adjusting for periodontitis, demographic, socioeconomic and behavioural variables root caries was significantly associated with sex, age, ethnicity, job classification, smoking, tooth brushing and periodontitis. Adults having PD or LoA ≥4mm showed a significant association with root caries RR: 1.23 (95%CI: 1.16-1.30) compared to those who had PD or LoA <4mm. Females had higher rates of developing root caries than males. Furthermore, root caries was significantly associated with the age groups. Adults occupying routine and manual jobs and those who brushed their teeth less often had significantly higher rates of root caries. In addition, former and never smoker had lower rates of root caries than current smokers. Unlike the association observed in the DMFT model, sugar consumption showed no association with root caries.

Discussion

In this study, we have found that in a nationally representative sample of England, Wales and Northern Ireland associations between periodontitis and each of coronal caries and root caries

exist. Even when covariates and some risk factors for caries were adjusted for in regression models, the association persisted. Smoking, age, toothbrushing showed a consistent and significant association with coronal and root caries. To the extent of our knowledge, this the is first study that examined the association between periodontitis and both of coronal and root caries in a nationally representative sample.

Periodontitis and root caries association observed in this study was in agreement with previous studies in which periodontitis was correlated with the prevalence of root caries(10, 11). Periodontitis is usually combined with recession of gingiva and exposure of root surfaces to aerobic flora of the mouth. The buffering action of saliva have a neutralising effect on pH level which can alternate the environment that surrounds the root into environment that favours cariogenic bacterial growth. This phenomenon can be used to explain the role of periodontitis on developing root caries, as root surfaces have higher susceptibility to caries compared to enamel in coronal surfaces(10). That aside, age can be considered a risk factor for periodontal disease and root caries. The literature showed that periodontal disease and root caries have a positive relationship with age(3, 11). These findings are consistent with our study results that root caries was higher among older participants and it was most prevalent among 55 years age group and older.

The findings of the present study support the hypothesis that periodontal disease has a positive association with coronal caries as reported in previous studies(12, 13, 17). While in the current analysis we do not argue for a causal relationship between periodontitis and coronal caries, Albandar, Buischi (12), using longitudinal data found that one of the risk factor for loss of periodontal attachment is the existence of proximal caries. Possible explanations for this association include the proximal plaque retention and the irritation caused by the cavity itself(13). Other explanations of this association are poor oral hygiene and age. Poor oral

hygiene was considered as one of the main risk factors for periodontitis and caries(2). Furthermore, It was found in a study by Bernabé and Sheiham (17) that caries increases with age. Similarly, periodontitis prevalence and severity are associated with age. In the current analysis of cross-sectional data there was a significant association between each of poor oral hygiene and age with coronal caries. It is possible that the observed relation between coronal caries and periodontitis is attributed to common risk factors, mainly age and poor oral hygiene.

On the light of the current findings, the mean of coronal and root caries was significantly associated with periodontal disease. This contradicts the genetic theory of antagonistic pleiotropy, which suggest that specific genes can make individuals susceptible to periodontal pockets but not to caries and vice versa.

Ethnicity showed a significant correlation with both coronal/root caries. British Black adults were at increased risk of developing root caries, while British Asian adults were at increased risk of developing coronal caries. This association could be influenced by the socioeconomic, cultural and behavioural factors such as diet and oral hygiene which have well known associations with both conditions(1).

It has been accepted in the public health literature that socioeconomic position indicators like education and income are risk factors for developing root and coronal caries, this was mainly attributed to their obvious impact on health-related behaviours, use of services, stress and other distal determinants of oral diseases(18). Others argued that the risk of consuming sugar in diet is a common risk factor for both caries and periodontitis development(1). Surprisingly, in our analysis, low level of education showed a significant association with coronal caries but not with root caries. Similarly, sugar consumption showed a significant association with coronal caries but not root caries. These two interesting finding could be explained by the attributes of

two disease measures or the effect of adjustment for other factors in the model, for instance, toothbrushing and smoking.

There were other significant predictors of coronal and root caries among participants. Coronal caries showed a strong and significant association with smoking which is similar to the finding of (1) study. Root caries also showed a strong association with smoking which is in line with another study (19). Another behavioural factor to consider is routine dental visits. In our study participants who indicated visiting the dentist less than one time yearly showed no association with coronal or root caries. Inconclusive and conflicting evidence exists regarding the benefits of routine dental check-ups. A systematic review reported lack of high-quality evidence supporting or refuting the recommendation of regular attendance of dental clinic of any frequency (20). Other studies argued that regular dental attendees had higher probability of adopting other health-related behaviour and therefore they have decreased caries experience and better oral health (21, 22). Thus, the recommendation of having regular dental check-ups remains a crucial practice in preventive dentistry.

It is well known that oral hygiene is a risk factor for caries development (2) and in the analysis of the present study the association of toothbrushing with coronal and root caries was in the expected direction, as tooth brushing frequency as proxy for oral hygiene have showed a strong association with coronal and root caries.

This study demonstrates associations between periodontitis and each of coronal and root caries in the same nationally representative population. While the association between periodontitis and root caries have been reported in a number of studies, only one study reported a positive relation between the extent of periodontitis and the coronal caries as an outcome (13). The findings of the current study could be beneficial in improving the risk assessment for both coronal and root caries.

There are some limitations in this study that have to be mentioned. First, causal relationships cannot be concluded from our results as they were drawn from a cross-sectional data. Second, it can be argued that the data used in this study is relatively old as it was collected in 2009. However, it is the latest nationally representative sample of the UK conducted in England, Wales, Northern Ireland and it provides an opportunity to explore and clarify the association between each of coronal and root caries and periodontitis. Additionally, the participation rate of the data collected (61%) may have affected the representativeness of the sample. However, this was inevitable as not all participants in the ADHS had periodontal assessments. Furthermore, the use of examination weight throughout the analysis account for the smaller number included in the clinical examination. Third, we were obligated to a pragmatic definition of periodontitis instead of a case definition based on the worst score of PD or LoA of each participant, and that is because of the nature of reporting the clinical assessment in the ADHS 2009. It is worth noting that if the current definition of periodontitis (23) were used, the estimate of periodontal cases would have been larger and would have influenced the associations observed here. Fourth: oral health behavioural factors were based entirely on a self-reported measure, opening the possibility of reporting bias, recall bias, social desirability bias. Nevertheless, even the objectives measures of oral health-related behaviour have some limitations (24).

To reach a conclusive result of the genetic role in the association between periodontitis and caries, longitudinal studies are needed to unravel the mechanism underlying the genetic association. Furthermore, longitudinal studies should be conducted to establish temporality and have a better understanding of the potentially modifiable risk for coronal and root caries such as smoking, sugar consumption frequency/amount concerning both diseases.

In conclusion, despite the limitations of our study, individuals with periodontitis appeared to be at higher risk of coronal and root caries. While root exposure could be a plausible explanation for the relationship between periodontitis and root caries, the association with coronal caries could be attributed to the irritation of carious cavities or a common risk factors such as poor oral hygiene, or co-occurrence of different health risk behaviours related to both caries and periodontitis and socioeconomic conditions.

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Author Contributions

LA conceived the research idea, conducted the analysis and wrote the first draft, WS conceived the research idea, advised on data analysis and edited the final draft.

Statement of Ethics

The authors have no ethical conflicts to disclose.

Disclosure Statement

The authors have no conflicts of interest to declare.

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References

1. Chapple IL, Bouchard P, Cagetti MG, Campus G, Carra MC, Cocco F, et al. Interaction of lifestyle, behaviour or systemic diseases with dental caries and periodontal diseases: consensus report of group 2 of the joint EFP/ORCA workshop on the boundaries between caries and periodontal diseases. Journal of clinical periodontology. 2017;44(S18).
2. Jepsen S, Blanco J, Buchalla W, Carvalho JC, Dietrich T, Dörfer C, et al. Prevention and control of dental caries and periodontal diseases at individual and population level: consensus report of group 3 of joint EFP/ORCA workshop on the boundaries between caries and periodontal diseases. Journal of clinical periodontology. 2017;44(S18).
3. Bignozzi I, Crea A, Capri D, Littarru C, Lajolo C, Tatakis DN. Root caries: a periodontal perspective. Journal of periodontal research. 2014;49(2):143-63.
4. Heasman PA, Ritchie M, Asuni A, Gavillet E, Simonsen JL, Nyvad B. Gingival recession and root caries in the ageing population: a critical evaluation of treatments. Journal of clinical periodontology. 2017;44(S18).
5. Durand R, Roufegarinejad A, Chandad F, Rompre PH, Voyer R, Michalowicz BS, et al. Dental caries are positively associated with periodontal disease severity. Clin Oral Investig. 2019.
6. Haerian A, Ezoddini F, Ardakani S, Vafadar S, Zafarbakhsh A. Determining the Relationship between Dental Caries and Periodontal Disease on the Panoramic Radiographies. SSU_Journals. 2014;22(5):1512-23.
7. Kinane DF, Jenkins WM, Adonogianaki E, Murray GD. Cross-sectional assessment of caries and periodontitis risk within the same subject. Community dentistry and oral epidemiology. 1991;19(2):78-81.
8. Iwano Y, Sugano N, Matsumoto K, Nishihara R, Iizuka T, Yoshinuma N, et al. Salivary microbial levels in relation to periodontal status and caries development. Journal of periodontal research. 2010;45(2):165-9.
9. Sioson PB, Furgang D, Steinberg LM, Fine DH. Proximal caries in juvenile periodontitis patients. Journal of periodontology. 2000;71(5):710-6.
10. López R, Smith PC, Göstemeyer G, Schwendicke F. Ageing, dental caries and periodontal diseases. Journal of clinical periodontology. 2017;44:S145-S52.
11. Saotome Y, Tada A, Hanada N, Yoshihara A, Uematsu H, Miyazaki H, et al. Relationship of cariogenic bacteria levels with periodontal status and root surface caries in elderly Japanese. Gerodontology. 2006;23(4):219-25.
12. Albandar JM, Buischi YA, Axelsson P. Caries lesions and dental restorations as predisposing factors in the progression of periodontal diseases in adolescents. A 3-year longitudinal study. Journal of periodontology. 1995;66(4):249-54.
13. Nascimento GG, Baelum V, Dahlen G, Lopez R. Methodological issues in assessing the association between periodontitis and caries among adolescents. Community dentistry and oral epidemiology. 2018;46(3):303-9.
14. O'Sullivan I, Lader D, Beavan-Seymour C, Chenery V, Fuller E, Sadler K. Foundation report: adult dental health survey 2009 (technical information). Adult dental health survey 2009. 2011:138.
15. Steele J, Treasure E, O'sullivan I, Morris J, Murray J. Adult dental health survey 2009: transformations in British oral health 1968–2009. British dental journal. 2012;213(10):523.
16. White D, Tsakos G, Pitts N, Fuller E, Douglas G, Murray J, et al. Adult Dental Health Survey 2009: common oral health conditions and their impact on the population. British dental journal. 2012;213(11):567.
17. Bernabé E, Sheiham A. Age, period and cohort trends in caries of permanent teeth in four developed countries. American journal of public health. 2014;104(7):e115-e21.
18. Marmot M, Bell R. Social Determinants and Dental Health. Advances in Dental Research. 2011;23(2):201-6.

19. BharateeSh JV, KoKila G. Association of root caries with oral habits in older individuals attending a rural health centre of a dental hospital in India. Journal of clinical and diagnostic research: JCDR. 2014;8(11):ZC80.
20. Patel S, Bay RC, Glick M. A systematic review of dental recall intervals and incidence of dental caries. The Journal of the American Dental Association. 2010;141(5):527-39.
21. Åstrøm AN, Ekback G, Ordell S, Nasir E. Long-term routine dental attendance: influence on tooth loss and oral health-related quality of life in S wedish older adults. Community dentistry and oral epidemiology. 2014;42(5):460-9.
22. Thomson W, Williams S, Broadbent J, Poulton R, Locker D. Long-term dental visiting patterns and adult oral health. Journal of Dental Research. 2010;89(3):307-11.
23. Alaeddini A, Jaramillo CA, Faruqui SHA, Pugh MJ. Mining Major Transitions of Chronic Conditions in Patients with Multiple Chronic Conditions. Methods Inf Med. 2017;56(5):391-400.
24. Sutton S, Baum A, Johnston M. The Sage handbook of health psychology: Sage; 2004.

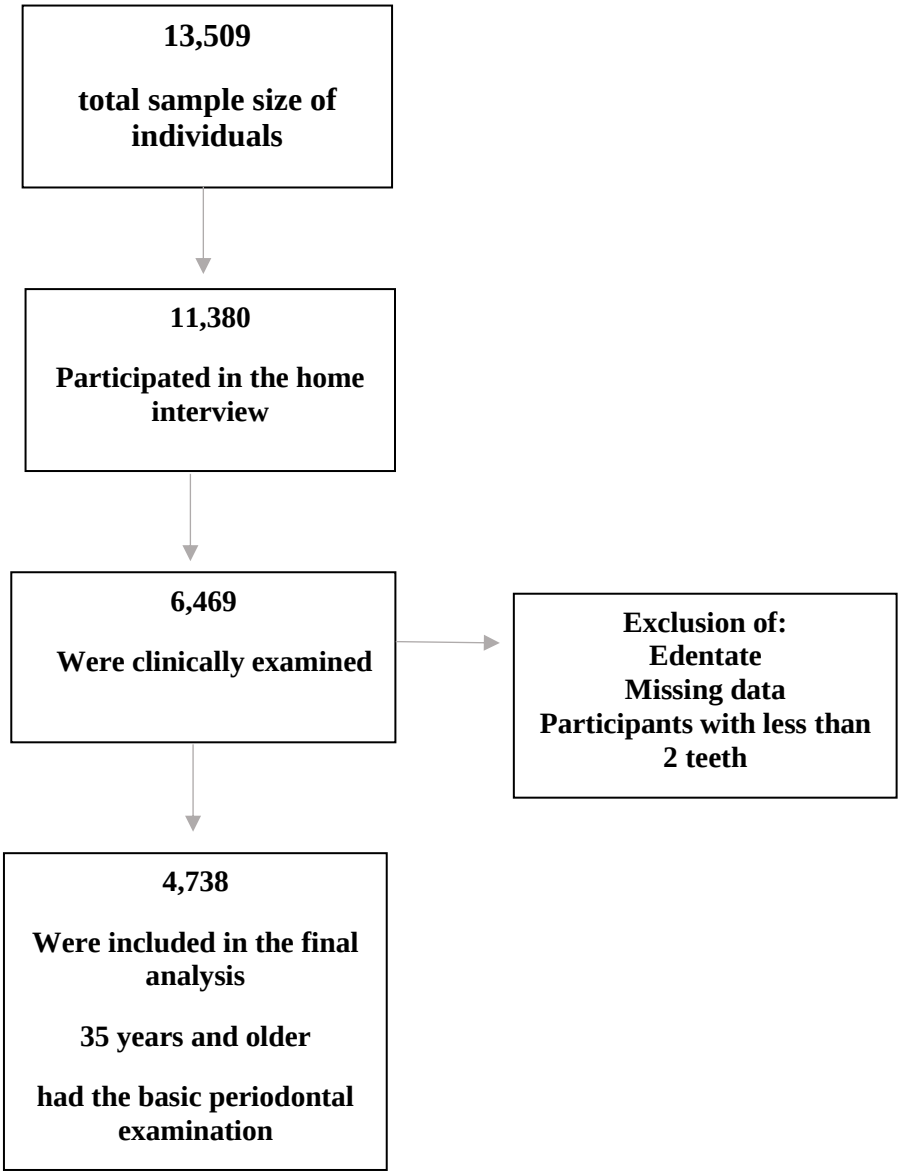

Figure 1. Flow chart of data collection

Table 1: Socio-demographic and behavioural characteristics of the study participants and the distribution of DMFT and Root Caries within the study variable in England, Wales and Northern Ireland 2009 (N=4738)

	Characteristics	N (4738)	Proportion / (95%CI)	Mean DMFT and root caries (95% CI)	
				DMFT	Root caries
Sex	Male	2,191	48.4% (46.8-50.0)	16.18 (15.84-16.53)	9.61 (9.27-9.96)
	Female	2,547	51.5% (49.9-53.1)	16.41 (16.13-16.69)	8.29 (7.99-8.59)
Age	35 to 44	1,242	29.3% (27.8-30.8)	11.54 (11.17-11.92)	6.29 (5.84-6.74)
	45 to 54	1,162	24.7% (23.4-26.2)	15.89 (15.53-16.24)	9.08 (8.60-9.56)
	55 or more	2,334	45.8% (44.3-47.4)	19.57 (19.31-19.83)	10.54 (10.25-10.83)
Country	England	4,117	91.5% (90.8-92.2)	16.15 (15.92-16.38)	8.95 (8.70-9.19)
	Wales	315	5.4% (4.8-6.1)	17.66 (16.92-18.40)	8.65 (7.90-9.40)
	Northern Ireland	306	2.9% (2.6-3.3)	18.45 (17.74-19.16)	8.92 (8.13-9.70)
Education	No Qualification	833	17.32% (16.14-18.56)	18.93 (18.36-19.49)	9.77 (9.26-10.28)
	Qualification, below degree	2,725	57.08% (55.48-58.67)	16.41 (16.14-16.69)	9.08 (8.78-9.39)
	Qualification, at degree level	1,180	25.6% (24.2-27.06)	14.28 (13.86-14.70)	8.02 (7.56-8.48)
NS-SEC3 Job classification	Managerial/professional	1,860	38.25% (36.7-39.82)	15.34 (15.00-15.69)	8.46 (8.09-8.82)
	Intermediate	1,089	23.05% (21.72-24.44)	16.57 (16.14-17.01)	8.89 (8.40-9.38)
	Routine and manual	1,608	34.48% (32.96-36.03)	17.09 (16.70-17.47)	9.46 (9.06-9.85)
	Never worked	181	4.21% (3.6-4.93)	17.07 (15.85-18.28)	9.13 (8.03-10.23)
Ethnicity	All white	4,438	91.0% (89.91-92.08)	16.80 (16.59-17.02)	9.09 (8.86-9.33)
	All Asia	172	5% (4.23-5.89)	9.32 (8.24-10.40)	7.72 (6.54-8.91)
	All black	61	2.0% (1.58-2.75)	13.84 (11.73-15.96)	5.41 (3.62-7.21)
	Other	67	1.86% (1.42-2.44)	13.16 (11.46-14.85)	8.23 (6.25-10.20)
Frequency of dental visits	At least every 6 months	2,762	55.6% (54.02-57.24)	16.53 (16.27-16.79)	8.91 (8.61-9.21)
	At least one a year	1,031	21.7% (20.46-23.14)	16.45 (15.99-16.91)	8.98 (8.48-9.47)
	Less than once every year	963	22.6% (21.23-24.03)	15.59 (15.01-16.17)	8.93 (8.42-9.44)
Smoking status	Current smokers	802	17.83% (16.6-19.13)	16.99 (16.48-17.50)	10.25 (9.67-10.82)
	Former smokers	1,809	37.7% (36.16-39.26)	17.05 (16.69-17.40)	8.99 (8.62-9.35)
	Never smoked	2,127	44.47% (42.88-46.08)	15.39 (15.06-15.72)	8.35 (8.01-8.70)
Toothbrushing	Twice a day and more	3,536	74.46% (73.02-75.84)	15.81 (15.56-16.05)	8.95 (8.68-9.22)
	Once a day or less	1,202	25.54% (24.16-26.98)	17.74 (17.27-18.20)	8.88 (8.44-9.31)
Periodontitis	Less than 4mm	2,214	46.4% (44.8-48.0)	15.49 (15.18-15.80)	7.65 (7.32-7.98)
	4mm and more	2,524	53.5% (51.9-55.1)	17.00 (16.70-17.31)	10.04 (9.73-10.36)

Table 2: Distribution of DMFT components and periodontitis by age groups

		Mean number of decayed filled and missing teeth			Percentage with periodontitis
		Decayed	Filled	Missing	
Age groups	35-44	0.84	6.75	4.41	0.43
	45-54	0.93	10.11	6.00	0.53
	55+	0.96	9.42	10.77	0.61

Table 3: Negative binomial regression analysis showing the association between DMFT and periodontitis, England, Wales and Northern Ireland 2009 (n=4738)

DMFT	Characteristics	RR / (95%CI)
Sex	male	Reference
	female	0.97** (0.94-0.99)
Age	35-44	Reference
	45-54	1.34*** (1.29-1.39)
	55 and over	1.62*** (1.56-1.67)
Country	England	Reference
	Wales	1.04* (1.00-1.09)
	Northern Ireland	1.16*** (1.11-1.20)
Ethnicity	All white	Reference
	All Asia	0.64*** (0.57-0.71)
	All black	0.90 (0.77-1.05)
	Other	0.89 (0.80-1.00)
Education	No qualification	0.96* (0.93-0.99)
	Qualification, below degree	0.91*** (0.87-0.94)
	Qualification, at degree level	Reference
NS-SEC3 Job classifications	Managerial/professional	Reference
	Intermediate	1.03 (0.99-1.05)
	Routine and manual	1.03 (0.99-1.05)
	Never worked	1.06 (0.99-1.11)
Smoking status	Current smoker	Reference
	Used to smoke	0.92*** (0.89-0.96)
	Never smoked	0.90*** (0.87-0.93)
Frequency of dental visits	At least every 6 months	Reference
	At least one a year	1.01 (0.98-1.04)
	Less than once every year	0.97 (0.93-1.00)
Toothbrushing	Twice a day and more	Reference
	Once a day or less	1.05*** (1.02-1.08)
Periodontitis	less than 4mm	Reference
	4mm and more	1.03** (1.01-1.05)
Sugar consumption		1.04*** (1.03-1.06)

***p < 0.001; **p < 0.01; *p < 0.05

Table 4: Negative binomial regression analysis showing the association between Root Caries and periodontitis, England, Wales and Northern Ireland 2009 (n=4738)

Root caries	Characteristics	RR / (95%CI)
Sex	male	Reference
	female	1.16*** (1.09-1.23)
Age	35-44	Reference
	45-54	1.43*** (1.31-1.57)
	55 and over	1.69*** (1.56-1.83)
Country	England	Reference
	Wales	0.94 (0.85-1.04)
	Northern Ireland	1.08 (0.97-1.20)
Ethnicity	All white	Reference
	All Asia	0.92 (0.78-1.08)
	All black	0.55*** (0.41-0.75)
	Other	1.04 (0.82-1.33)
Education	No education	1.04 (0.97-1.11)
	Educational with degree	0.89 (0.89-1.08)
	Education without degree	Reference
NS-SEC3 Job classifications	Managerial/professional	Reference
	Intermediate	1.03 (0.95-1.12)
	Routine and manual	1.07* (1.00-1.16)
	Never worked	1.02 (0.90-1.16)
Smoking status	Current smoker	Reference
	former smokers	0.81*** (0.75-0.88)
	Never smoked	0.80*** (0.74-0.87)
Frequency of dental visits	At least every 6 months	Reference
	At least once a year	1.05 (0.98-1.12)
	Less than once every year	1.00 (0.93-1.08)
Toothbrushing	Twice a day and more	Reference
	Once a day or less	0.87*** (0.81-0.93)
Periodontitis	less than 4 mm	Reference
	4mm and more	1.23*** (1.16-1.30)
Sugar consumption		1.00 (0.96-1.04)

***p < 0.001; **p < 0.01; *p < 0.05